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1.	Your reference	P100773GB
2.	Patent application number *(The Patent Office will fill in this part)*	0222341.0 26 SEP 2002
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	British Nuclear Fuels plc Risley WARRINGTON Cheshire WA3 6AS
	Patents ADP number *(if you know it)*	35010800l
	If the applicant is a corporate body, give the country/state of its incorporation	
4.	Title of the invention	Surface Treatment of Concrete
5.	Name of your agent *(if you have one)*	Harrison Goddard Foote
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Orlando House 11c Compstall Road Marple Bridge Stockport SK6 5HH United Kingdom
	Patents ADP number *(if you know it)*	14571002

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8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
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Description	18
Claim*(s)*	4
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Priority documents	0	
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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	0	
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Request for substantive examination *(Patents Form 10/77)*	0	
Any other documents *(please specify)*	2	Covering letter and fee sheet

11. I/We request the grant of a patent on the basis of this application.

Signature Harrison Goddard Foote — Date 25/9/02

Harrison Goddard Foote — 25/9/2002

12. Name and daytime telephone number of person to contact in the United Kingdom — David Goddard — 0161 427 7005

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P100773GB

Surface treatment of Concrete

Field of the invention

The present invention concerns surface removal from inorganic non-metallic structures, in particular concrete structures, primarily though not exclusively for the purpose of removing radioactive contamination contained in surface layers.

Discussion of the Prior art

In the nuclear industry surfaces of concrete structures may become contaminated with radionuclides. Common contaminants include uranium oxide, plutonium oxide, strontium-90, caesium-137 and cobalt-60. Typically this contamination is only present in a surface layer of concrete. Such layers may be around 1 to 4mm thick. By removal of such a surface layer the degree of contamination of a surface and of the structure as a whole may be greatly reduced. However, simple mechanical methods are unsuitable for use where a potential for contamination makes it desirable for an operator to be remote from a surface to be operated upon.

Various techniques are known for the surface removal of concrete, stone and similar surfaces. One such method is the heat treatment of a surface such as to degrade that surface and release a surface layer.

JP 3002595 describes the removal of a concrete surface layer by crushing due to the heat generated by the use of microwaves to irradiate a contaminated surface layer.

EP-A-0653762 describes a method of modifying concrete using a laser by a method of ejecting surface chips, thus causing surface removal, using a laser scanned across a surface in a raster scan is disclosed. In such methods energy from laser light causes surface chips to break away due to generation of steam or thermal stresses below the surface thus effecting surface removal. This latter phenomenon of ejecting surface chips or flakes is known in the art as laser scabbling.

However, it has been found that some surfaces, including some types of concrete having aggregate therein, whilst successfully scabbling on a first scan, may fail to do so on areas which are adjacent a first scanned track when subjected to laser irradiation on a subsequent adjacent scanned track.

Summary of the invention

According to the present invention there is provided a method of treating a surface for the removal of a surface portion comprising the steps of: irradiating the surface with laser light characterised in that the irradiation is effected by covering said surface in a plurality of

discreet (sequential) spots of laser light (in a sequential manner).

The spots of laser light may be applied sequentially. The locations may be defined by the centres of the spots of laser light. The spots of laser light may overlap.

The method substantially avoids the creation of areas treated by the laser light which subsequently resist laser scabbling. In addition the method results in a flatter scabbled surface than with known methods of laser surface treatment.

At least two problems have been found in the prior art with surface removal by scabbling using a laser. Both problems are associated with a non-uniform power distribution, for example, quasi-Gaussian, across a laser beam spot, in particular with the presence of lower intensity parts of an incident beam of laser light on the surface to be treated. The part of a beam of laser light incident upon a surface that is above a critical energy or threshold energy level intensity for effecting scabbling gives rise to scabbling from the surface. However, a usually peripheral part of an incident laser beam which is below the threshold energy level intensity, i.e. a part not subjecting a surface portion on which it is incident to an energy intensity above a critical value, does not give rise to surface removal by scabbling. However, such a surface portion, and adjacent similarly un-scabbled areas, may be sufficiently affected by heating from the energy of the incident laser

beam that a number of processes may occur in the surface portion, such as relaxation, dehydration and chemical change. These processes can result in the affected surface no longer being amenable to subsequent surface removal by scabbling from incident laser light, even when that light is above the threshold energy level intensity for scabbling. That is at least when laser light is used in a manner whereby surface removal is otherwise effected by scabbling, i.e. the ejection of surface chips.

Furthermore a non-uniform power distribution across a laser beam incident upon a surface may result in differential surface removal by scabbling between surface portions where a highest and a lower energy, both of which are above the threshold energy level intensity, are incident. For this reason a channel with sloping sides may be formed in a surface by a scanned laser beam impinging perpendicular to a surface. A further, adjacent, scanned track, by such a perpendicular beam may result in laser light impinging upon a sloping surface portion resulting in a lower incident energy intensity per surface area. The sloping sides may therefore cause an otherwise sufficient energy intensity, per unit area, to become insufficient, i.e. to fall below a threshold energy level intensity or to scabble less surface material. As a result a whole surface when scabbled using laser light may be uneven.

In addition scabbling processes using lasers may cause explosive detachment of surface portions of a material being treated, as in the scabbling of concrete. To overcome

shrapnel damage to the laser and associated optics, laser beams may be focussed through a relatively very small aperture, through which air may also be ejected under pressure so as to additionally prevent ingress of debris. Such focussing may serve to increase the divergence of a laser beam, due to the surface to be treated being remote from the focus, and induce or increase a spread of energy intensity within a spot of incident laser light.

The use of spots, particularly overlapping spots, of laser light to scabble a surface has been found to reduce the effect of the peripheral part of a laser beam, a part not reaching a threshold energy intensity for causing scabbling, and which may therefore inhibit further surface removal. Surprisingly, it has been found that whilst the area subjected to a lower incident laser beam energy intensity, i.e. an energy intensity below a critical threshold, is increased using the method of the invention as compared to a scanned laser beam, the efficiency of surface removal is increased and a more even scabbled surface results.

Said plurality of spots of laser light may be arranged in a geometric arrangement. The geometric arrangement may be defined by the arrangement of the locations the centres of the spots of laser light.

A centre of a spot of laser light may be defined as the geometric centre of the spot of incident laser light. A

centre of a spot of laser light may be the highest energy intensity part of an incident spot of laser light.

The geometric arrangement of a plurality of spots of laser light may be that of a simple geometric figure. Suitable simple geometric figures include triangles, rectangles, rhombi, pentagons, hexagons and the like. The simple geometric figure is preferably an equilateral triangle. The simple geometric figures may be tessellated, that is fit together exactly to cover a surface without gaps between the figures. The spots of laser light may be arranged as a series of geometric arrangements, such as a series of triangles, so that an array of spots of laser light is described on the surface by the method.

The extent of the overlap of overlapping spots of laser light may be such that no area not, at one time during use of the method, exposed to laser light is present between the locations of the spots of laser light.

The spots of laser light may be ovoid. The spots of laser light may be ellipsoidal. The spots of laser light may be square or rectangular. The spots of laser light may be circular. The width of a spot of laser light may be a diameter of an incident spot of laser light. In one embodiment of the method of the present invention the distance between the centres of the spots of laser light may be in the range 4/7 (?) to 6/7 (?), and preferably 5/7 (71%) of a spot diameter measured as that diameter of the spot exceeding a threshold energy level for scabbling.

A spot of laser light may be defined as an area of laser light incident upon a surface, wherein the area is an area above a threshold energy level for causing scabbling. The diameter of a spot of laser light may be a diameter of the area of a spot of laser light above a threshold energy level for causing scabbling.

In one embodiment of the present invention using a 4kW YAG laser the total diameter of an area of a surface upon which incident laser light falls may be from 20mm to 250mm in diameter and more preferably from 70mm to 130mm in diameter. In such an embodiment the width of the spot of laser light above a threshold energy level intensity to cause scabbling, may correspondingly be from 30 to 80 mm or 65 and 75 mm in the preferred range.

If sequential spotting of laser light is used the time between subsequent spots of laser light may be between ???s and ???s, preferably between ???s and ???s.

The time of irradiation of a surface location for any given spot may be between ???s and ???s. The time interval between each successive spot of laser light being applied may be substantially equal.

Any suitable method of creating individual spots of laser light for laser irradiation may be used. A continuous laser beam may be interrupted by a shutter or the beam may be turned on and off. More than one laser source may be used.

Any suitable method for moving the individual spots of laser light of laser irradiation may be used including moving the laser, moving the object to be scabbled, moving a conduit (such as a fibre-optic cable) or optical methods such as mirrors and the like. It is within the scope of the invention to move a beam, without turning it off, at such a velocity that the beam has a negligible residence time between individual spots of laser light such that individual incident spots of laser light are effectively created.

The spots of laser light irradiation for use in the invention may have an uneven radiation intensity across the beam.

A laser light source for use in the invention may typically be of total energy from 0.5 kW to 4 kW.

A threshold energy level intensity for surface removal by scabbling for concrete may typically be in the range of ??kW/mm^2 to ??kW/mm^2.

The energy of the laser, the size of the incident spot of laser light and the residence time of a spot of laser light are interrelated and for any given surface will be optimised so as to achieve most effective surface removal. The interrelationships of the above factors are governed by established physical laws known to the person skilled in the art.

A suitable laser source may be a Yttrium Aluminium Garnet (YAG) laser. Laser light sources for use in the invention may have a non-uniform energy intensity in cross-section.

It has been found that concrete removal depths of about ??mm to ??mm may be achieved using an array of spots of laser light according to the method of the invention.

Multiple arrays of spots of laser light may be applied subsequent to one another to a surface to achieve a greater depth of surface removal by removing layers in a sequential manner. The array of spots of laser light for subsequent irradiations may be placed out of alignment with a previous array. The location of spots of laser light, of sequential arrays applied to a given area may be placed at the interstices of previous arrays, so as to define a three dimensional matrix.

The laser beam may be transmitted to a delivery head by means of a fibre optic cable. The laser beam may be alternatively described as laser light or laser radiation.

A delivery head for projecting a laser beam onto a surface to be treated may comprise focussing optics to focus the beam through a focal point. The optics may include means for changing the direction of the laser light through a right angle. The beam and any optics may be shrouded up to the focal point. The shroud may be frusto conical. After the focal point the beam may diverge before impinging upon

a surface to be treated. The surface to be treated may be 270mm from the focal point when optics of focal length 120mm are used giving a spot of incident laser light of around 70mm on the surface to be treated.

Suitable laser equipment for practising the invention is supplied by TRUMPF GmbH and Co.KG. of Stuttgart, Germany. The laser may be guided by a robotic arm.

The laser beam may effect surface removal by the effects of thermal shock. The method of the invention may give no or negligible surface removal by melting or vaporisation of the surface being treated.

The method may comprise a step of wetting the surface to be treated before irradiation with the laser beam.

The method may comprise a step of coating the surface to be treated before irradiation with laser light. Examples of, suitable coatings are described in EP 0 653 762 A1.

The presence of radionuclides may affect the nature of the scabbling process and the adsórbtion of incident laser radiation.

The method of the invention may typically be used for decontamination in conjunction with fume extraction and other subsidiary protective processes to prevent the spread of any contamination, particularly where radioactivity is involved.

The surface for treatment according to the method of the invention may be an inorganic non-metallic surface such as a concrete, i.e. a cement, e.g. Portland cement, matrix having aggregate therein. The surface may alternatively comprise a natural stone such as limestone, for example.

Brief description of the drawings

In order that the present invention may be more fully understood, examples will now be given by way of illustration only, with reference to the accompanying drawings, in which :

Figure 1 shows a schematic representation of radiation intensity across a laser beam;

Figure 2 shows a schematic representation of an incident spot of laser light;

Figure 3 shows schematically a known method of laser scabbling comprising scanning a laser beam over a surface to be scabbled;

Figure 4 shows schematically an example of a pattern of spots of laser light for scabbling a surface in accordance with the invention;

Figure 5 shows schematically detail of the example shown in Figure 4 of a pattern of laser light irradiation in accordance with the present invention shown in;

Figure 6 shows schematically a further example of a pattern of laser light irradiation of a surface in accordance with the present invention;

Figure 7 shows schematically a which shows a yet further example of a pattern of laser light irradiation of a surface in accordance with the present invention; and

Figure 8 which shows a schematic representation of laser equipment suitable for use in the method of the invention

In the accompanying figures like features are denoted by like reference numerals.

Description of preferred embodiments of the invention

A beam of laser light may be non-uniform in intensity across a width of the beam. A schematic representation of energy intensity across a laser beam is shown in Figure 1. Figure 1 depicts a graph 2 with a y axis of radiation intensity (I) and an x axis of distance (d) across the beam. The curve 4 describes a quasi-Gaussian type energy distribution from which it may be seen that the laser beam has a central area 16 of highest energy intensity. The curve may be divided into two portions, the boundary between being defined by a threshold energy level intensity

18. A portion 6 of the curve 4 above this threshold represents part of the laser beam capable of giving rise to scabbling of a surface, the portion 8 below represents an area not capable of giving rise to scabbling of such a surface. However, the low intensity portion 8 may give rise to surface modification which makes the surface resistant to scabbling by subsequent passes with a laser beam having an energy intensity above the threshold 18.

Figure 2 depicts a representation of a laser beam, of uneven intensity profile, such as described in Figure 1 when impinged, orthagonally, upon a surface. The surface, such as one to be scabbled is represented here and in other diagrams by the plane of the paper. The spot of laser light 20 comprises a centre 12 of highest energy intensity and an immediately surrounding area 16 of high energy intensity. The centre point 12, and area 16, forms part of area 24 wherein the light is above a threshold energy intensity 18 for scabbling. Towards the periphery of the spot of laser light scabbling may be less effective (i.e. less material may be removed) until a boundary 14 is reached which corresponds to the threshold energy intensity 18 for effecting scabbling. A further area 26 of low incident energy exists between the first boundary 14 and a nominal outer boundary of the beam and is described by line 28 beyond which point incident light intensity is very low, such as may be due to scattering, for example.

In the prior art an incident spot of laser light may be used to scabble a surface by traversing that surface in a

known raster scan pattern 32. Figure 3 schematically depicts features 30 of such a method. Incident laser spot 20 moves over the surface in a raster scan pattern traced by the centre of the spot 12 along a line 32. The surface impinged upon by the high-energy intensity area of the spot at and within the boundary 14 scabbles. That impinged upon by the low energy intensity part of the area of laser light 26 does not scabble but the surface is modified to varying degrees by effects such as relaxation, dehydration and chemical change. This occurs as the incident beam 20 traverses a first track 37, area 38 of the spot leaving modified, but un-scabbled surface area 36. Other surface area traversed by the low intensity part of the laser light is also traversed by the higher intensity area and thus scabbles. Subsequently the laser spot traverses a second, adjacent, track 39. The surface impinged upon by the high energy intensity area 24′ of the spot 20′ generally scabbles. However, surface area 36 substantially resists scabbling even though it is impinged by the high energy intensity part 24′ of the incident laser light. This is a significant disadvantage with current laser scabbling methodology.

The method of the invention relates to an improved method of treating a surface to be scabbled.

Figure 4 shows a pattern 40 of spot irradiation for the scabbling of a surface in accordance with the invention. A laser beam (not shown) is made to momentarily impinge as a spot 20 of light on a concrete surface to be scabbled (as

represented by the plane of the paper) for ???ms. The spot is then turned off, the laser moved, and a subsequent spot 20'' irradiated for the same length of time in an adjacent position. The spot is then turned off and a further spot 20''', overlapping spots 20 and 20'', is then irradiated. Still further spots of laser light as indicated by other circles are then irradiated. An array of spots of laser light is therefore built up as indicated. This may be visualised by identifying the centres of spots 12, 12'', 12'''. Joining the centres of such spots of laser light with notional lines 42 to establish a geometric shape, in this example represented as an equilateral triangle 44. This is an example of a simple geometric shape as referred to previously.

Detail of the effects of scabbling as illustrated in Figure 4 are shown in Figure 5. An initial spot of laser light 20 causes scabbling in area 24. Area 26, of energy intensity below the threshold energy intensity for scabbling may start to become modified in such a way as to inhibit scabbling. The incident laser light is then moved to a second location 20'' and further scabbling in area 24' occurs. Area 24' encompasses area 52 and any difficulty in scabbling due to prior irradiation with area 26 is overcome with the high energy, higher near the centre 12'', area of incident laser light 24'. The relatively small area indicated at 54 is further irradiated with lower energy laser light and may become difficult to scabble. However, when the incident spot of laser light is moved to location 12''' the potentially difficult to scabble small area 54 is

located near the highest intensity part 16 of the laser spot 20''' and is given the a higher incident energy than the threshold energy intensity for scabbling present along boundary 14'''. The method of irradiating a surface for scabbling according to the method of the invention therefore enables the highest energy intensity part of an incident laser beam to impinge upon that part of a surface to be scabbled that is most likely to be resistant to scabbling.

As scabbling of the surface occurs with each spot a layer of the surface of the concrete is thereby systematically detached. The detached material may be ejected with some force or may be removed by air pressure or vacuum and collected.

In alternative uses of the method of the invention alternative permutations of spot irradiation sequences may be used. Examples of such sequences are illustrated in Figures 6 and 7. In Figure 6 a pattern of laser spot irradiation 60 is shown. The method comprises irradiating sequential spots of light 20, 20'' and so on along in an extended linear path 62 to scabble a line along the surface. A similar parallel row 63 of spots of laser light, offset by about a radius of the spots in a longitudinal direction from the first row of spots are then used to scabble the surface. Further rows, such as row 64 are then added to further scabble the surface. As the centres of the spots of laser light in a further row 63 are placed near the indentations 66 in an adjacent track 62 even scabbling

of the surface occurs giving a relatively even surface and concentrating the most effective part of a laser spot for scabbling at or near regions 66 (c.f. combined regions 52 and 54) least likely to scabble.

A further pattern of irradiation of a surface with spots of laser light for effecting scabbling is shown in Figure 7. Sequential spots of laser light 20, 20'' and 20''' are used to irradiate the surface for scabbling. The sequence of spots follows the sequence indicated by lines 70, 72, 74, 76 and describes a herring-bone pattern upon the surface being scabbled. This variant of the method of the invention has the advantage that areas 66 are irradiated for scabbling soon after their creation by earlier spots of laser light in the sequence (20, 20'', 20''' etc).

A schematic representation of laser equipment suitable for use in the method of the invention is shown in Figure 8. A laser light source 100, emits laser light which may be channelled along a fibre optic channel 102 to focussing optics 104. The focussing optics comprise lenses to focus the laser light to a focus 106. The laser light is shrouded by a frusto conical shroud 108, one end 110 of which surrounds the focal point of the laser light. The shroud serves to protect the optics and other components and forms part of an overall protective shroud (not shown) of the equipment. Compressed air is ejected through the end of the shroud 110 to also stop ingress of debris such as fumes and particles. Outside the equipment the laser light diverges 112 and impinges upon a surface to be treated 114.

The laser equipment may be mounted on a robotic arm for movement about a surface to be scabbled. Alternatively a robotic arm may move a laser head for emitting laser light on to a surface to be scabbled wherein the head is connected to a stationary laser source by a fibre optic cable.

Claims

1. A method of treating a surface for the removal of a surface portion comprising the steps of: irradiating the surface with laser light characterised in that the irradiation is effected by covering said surface in a plurality of discreet (sequential) spots of laser light (in a sequential manner).

2. A method of treating a surface according to claim 1 wherein the spots of laser light overlap.

3. A method of treating a surface according to either claim 1 or claim 2 wherein said plurality of spots of laser light are arranged in a geometric arrangement defined by the locations of centres of the spots of laser light.

4. A method of treating a surface according to claim 3 wherein the geometric arrangement of a plurality of spots of laser light is that of a simple geometric figure.

5. A method of treating a surface according to claim 4 wherein the simple geometric figure is chosen from the group consisting of triangles, rectangles, rhombi, pentagons, and hexagons.

6. A method of treating a surface according to claim 5 wherein the simple geometric figure is an equilateral triangle.

7. A method of treating a surface according to any one of claims 4, 5 or 6 wherein the simple geometric figures are tessellated.

8. A method of treating a surface according to any one of claim 2 to 7 wherein the extent of overlap of overlapping spots of laser light are such that no area not, at one time during use of the method, exposed to laser light is present between the locations of the spots of laser light.

9. A method of treating a surface according to any previous claim wherein the spot of laser light is circular.

10. A method of treating a surface according to claim 9 wherein a distance between the centres of the spots of laser light is in the range 4/7 to 6/7 of the diameter, above a threshold energy level intensity for scabbling, of the circular spot of laser light.

11. A method of treating a surface according to any previous claim wherein the spots of laser light are defined as an area of laser light incident upon a surface, wherein the area of laser light is that area above a threshold energy level for causing scabbling.

12. A method of treating a surface according to any previous claim wherein the incident laser light has an incident energy density range of ??kW/mm^2 to ??kW/mm^2.

13. A method of treating a surface according to any previous claim wherein each spot of laser light irradiates the surface for between ??s and ??s.

14. A method of treating a surface according to any previous claim wherein the spots of laser light for use in the invention have an uneven radiation intensity across the beam.

15. A method of treating a surface according to any previous claim wherein multiple arrays of spots of laser light are applied subsequent to one another to a surface to achieve a greater depth of surface removal by removing layers in a sequential manner.

16. A method of treating a surface according to claim 15 wherein the location of spots of laser light of sequential arrays are placed at the interstices of previous arrays, so as to define a three dimensional matrix.

17. A method according to any previous claim wherein the laser is an Yttrium Aluminium Garnet (YAG) laser.

18. A method according to any previous claim wherein the surface is a concrete surface.

19. A method according to claim 18 wherein the surface is a concrete surface contaminated with radionuclides.

20. A method according to any previous claim wherein the surface portion is removed by the effects of thermal shock.

21. A method of treating a surface for the removal of a surface portion substantially as hereinbefore described with reference to the accompanying description and any one of drawings 4, 5, 6 and 7.

Abstract

A method of treating a surface for the removal of a surface portion is described comprising the steps of: irradiating the surface with laser light characterised in that the irradiation is effected by covering said surface in a plurality of discreet (sequential) spots of laser light (in a sequential manner). The spots of laser light overlap and may be arranged in a geometric arrangement defined by the locations centres of the spots of laser light. The spots of laser light may be applied sequentially.

Figure 1

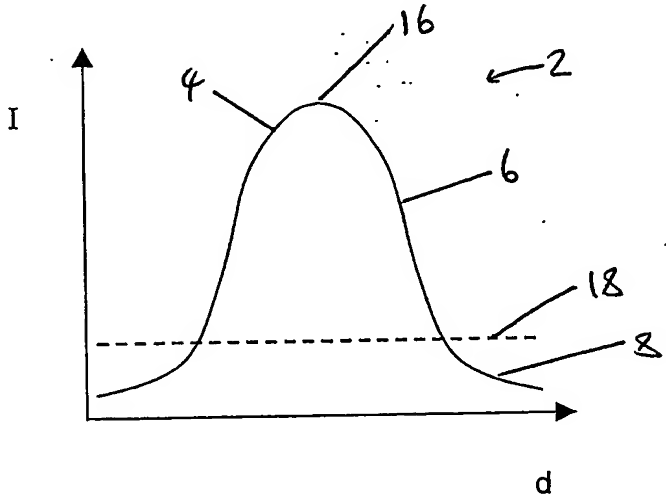


Figure 2

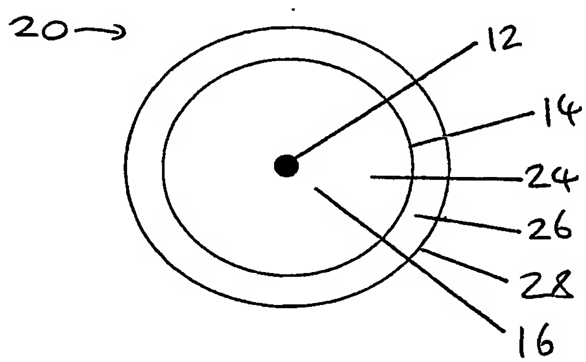


Figure 3

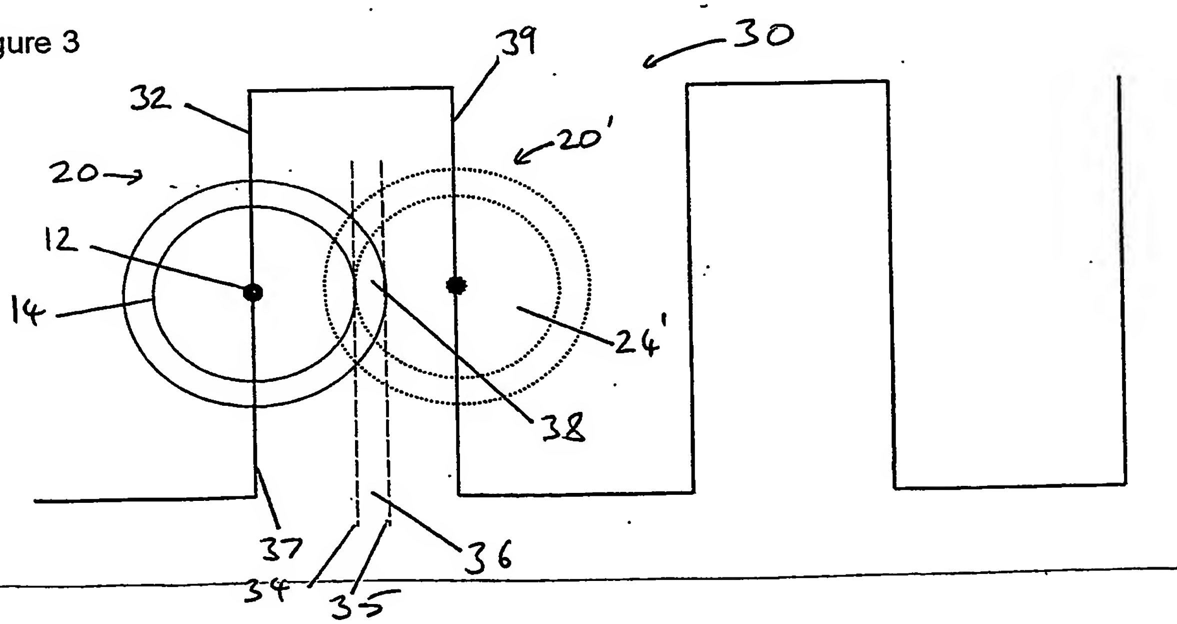


Figure 4

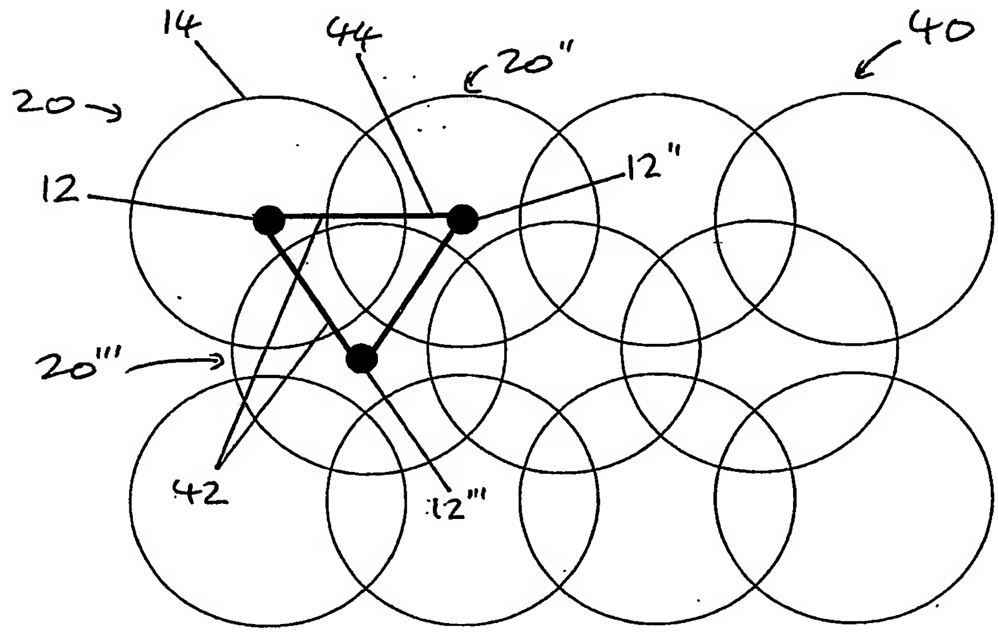


Figure 5

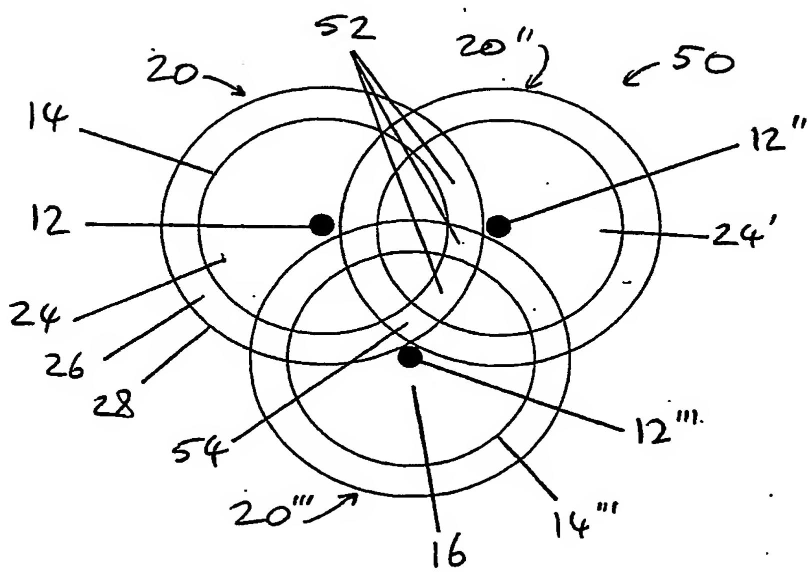


Figure 6

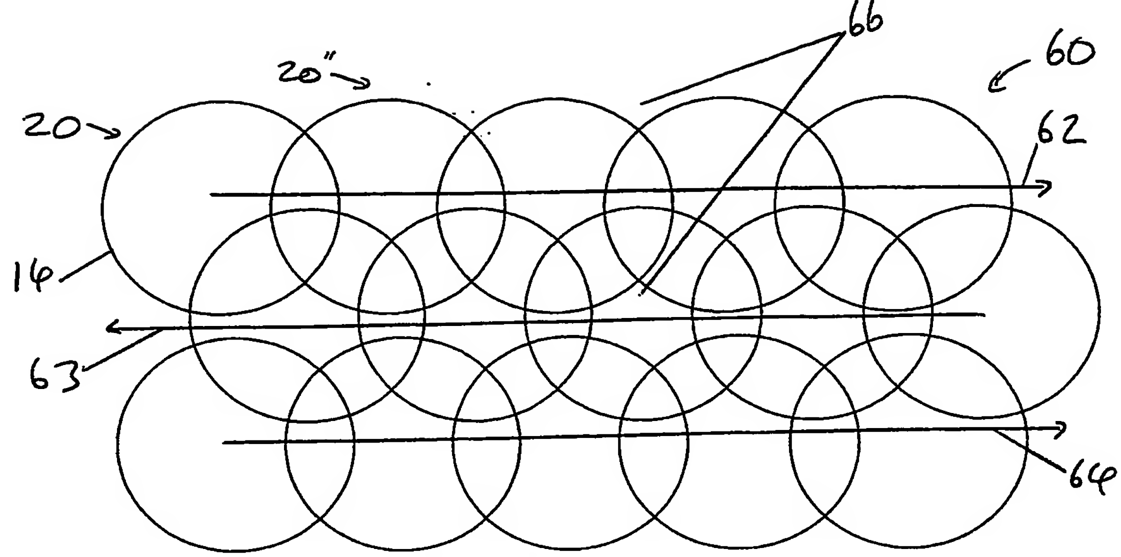


Figure 7

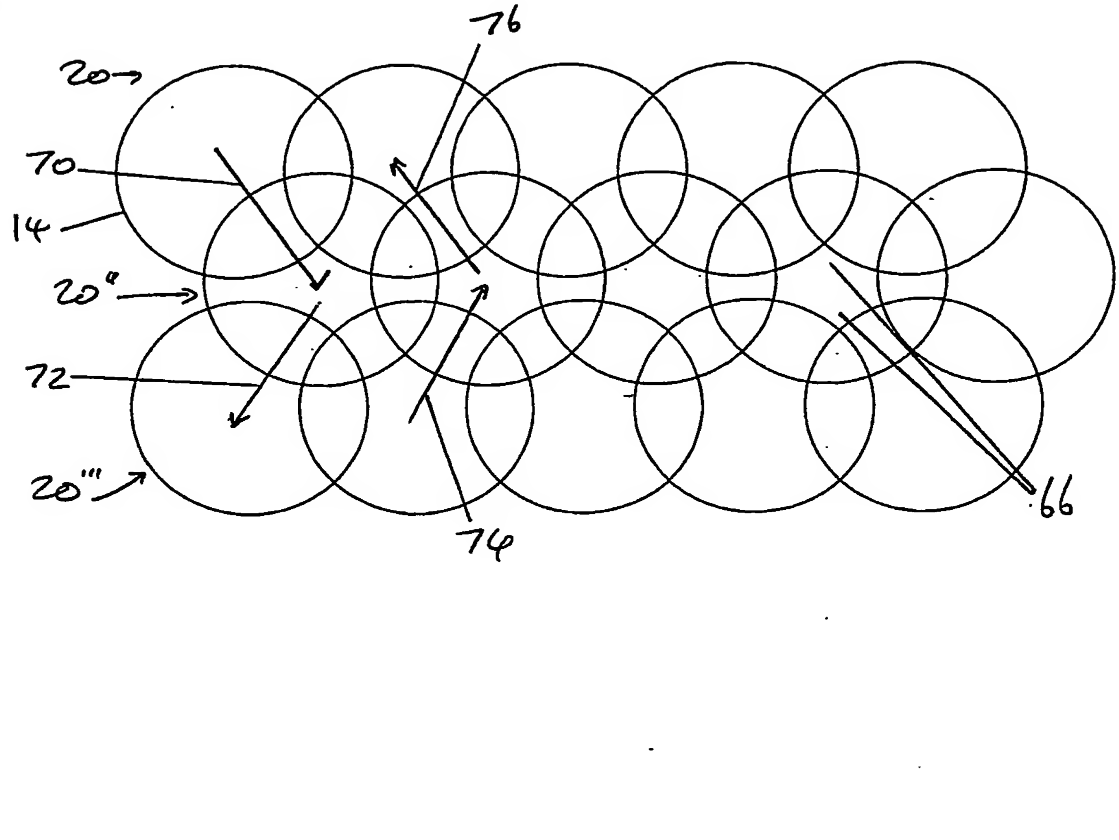
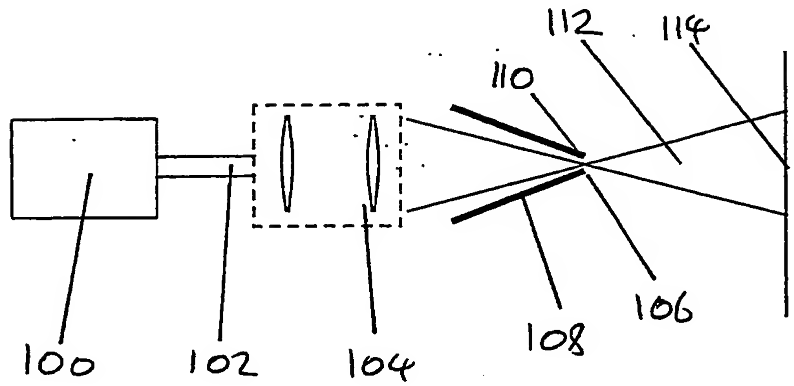


Figure 8



PCT Application
GB0304103